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Performance of fennel (*Foeniculum vulgare* Mill.) Cultivars under different irrigation levels

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Abstract
A field experiment was conducted during *Rabi* 2019-20 at Instructional Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner to study the effect of irrigation levels on growth and quality of fennel cultivars. The treatments comprised of four irrigation levels (0.55, 0.70, 0.85 and 1.0 PE) and four fennel cultivars (RF-101, RF-125, RF-143, and RF-205). The results revealed that growth and quality parameters of fennel cultivars were significantly increased by increasing irrigation levels. Highest plant height at 60 DAS and harvest (76.42 and 147.22cm, respectively), number of primary and secondary branches/plant (6.53 and 8.42, respectively), dry matter accumulation at 60, 100 DAS and at harvest (13.55, 30.01 and 51.99 g/plant, respectively), protein content in seed (9.25 per cent) and oil content in seed (1.67 per cent) were recorded with crop irrigated at 1.0 PE irrigation levels but it was remained statistically at par with 0.85 PE. Among the fennel cultivars, significantly highest plant height at 60 DAS and harvest (76.06 and 140.76 cm, respectively), number of primary and secondary branches/plant (6.03 and 8.04, respectively), dry matter accumulation at 60, 100 DAS and at harvest (13.03, 28.78 and 48.19 g/plant respectively) was recorded in RF-205 cultivar. Maximum protein content (1.81 per cent) was recorded in RF- 125 fennel cultivar as compared to rest of cultivars.

Keywords: Fennel, irrigation, cultivars, protein and oil

Introduction
The Fennel (*Foeniculum vulgare* Mill.) is an important seed spice in India mainly grown in *rabi* season. Fennel belongs to family Apiaceae. *Foeniculum* is diploid having 2n=22 chromosomes. It is a native of Southern Europe and Mediterranean. During the thirteenth century in England, fennel was considered as a royal spice and was served to kings with fruits. The most common Indian name is '*Saunf*' and there are many popular regional names. It is widely cultivated throughout the temperate and subtropical regions of the world and major growing countries are Romania, Russia, Germany, France, Italy, India, Argentina and USA. Major fennel producing states in India are Gujarat Rajasthan, Karnataka, Maharashtra, U.P., Punjab and Bihar. (Lal *et al.*, 2014) [9]. Fennel is a cool season crop, mainly cultivation during winter season in north India, and does not thrive in south India except at higher elevation. The optimum temperatures for seed germination are 20-27 °C. A dry and cool weather favours higher seed production. Fennel thrives on long sunny days. A temperature of 15-22 °C is the optimum and above 26 ^{0}C for extended period usually retards development of fennel and particularly in early growth stage may result premature flowering and very low seed yield. Its cultivation should be avoided in frost prone areas because it is susceptible to frost at flowering stage. Though during maturity, crop requires warm climate but high winds at the time of maturity can cause shattering of seed and very hot winds at flowering reduce seed setting. Dry as well as moderately cool weather conditions during seed formation stages increase seed yield as well as quality of the produce. A dry and cold weather favours higher seed production (Lal *et al.* 2014) [9].
The limited quantity of water available in Rajasthan for irrigation calls for an urgent need for application of water at appropriate intervals for ensuring better water use efficiency. The PE approach allows the preparation of irrigation time table for different crops. PE based scheduling of irrigation is a proper approach for applying irrigation water through drip system for optimum yield potential of fennel crop as it includes all the environmental parameters. In order to ensure water saving drip system comes out to be an effective tool in saving inputs like water and fertilizer by allowing water through drippers slowly to the root zone of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters.

To reduce input cost, drip system is very useful for horticulture crop production in arid region (Kumar *et al.* 2016). It is fact that particular genotypes do not exhibit the same phenotypic characteristics in all environmental circumstances. The responses of qualities, yield attributes and yield potential as well of genotype varies for a specific or different date of sowing (Dinda *et al.,* 2015) [4]. It is, therefore, felt that different cultivars be evaluated under drip irrigation, in western arid conditions of Rajasthan. Therefore, the investigation was conducted with an objective to find out suitable cultivars, optimum irrigation water requirement for realizing higher growth and yield of fennel.

Material Methods

The field experiments were conducted at Instructional Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan, India (28º 01'N latitude and 73º22'E longitude at an altitude of 235 meters above mean sea level) during *Rabi* season of 2019-20. The soil of experimental field was loamy-sand, alkaline in reaction (pH 8.5) having 117 kg/ha available N (Alkaline permanganate method (Subbiah and Asija, 1956) [20], low level of available phosphorus (15.4 kg/ha, Olsen's method (Olsen *et al*., 1954 [15] and medium in available potassium (172.7 kg/ha, Flame photometric method (Metson, 1956) [14] in 0-15 cm soil depth at the start of the experiment. The treatment combination of four levels of irrigation (0.55, 0.70, 0.85 and 1.0 PE) and four cultivars (RF-101, RF-125, RF-143 and RF-205) were randomly allotted to main plots and sub plots using random number tables of Fisher (1950). The seeds of fennel were sown on 24th October 2019. Sowing was done by *khera* method and seed rate 10 kg/ha at the depth of 2-3 cm. Three hard weeding was done manually at 30, 60 and 90 DAS with the help of hand hoe to keep the plot weed free. Recommended dose of N and P_2O_5 i.e. 90:40 Kg per ha was applied through urea and DAP, respectively. The seeds were treated with bavistin @ 3 g/kg seed just before sowing to protect the crop from seed borne disease. In order to maintain the uniform plant stand at a paired row spacing of 30 x 70 cm, extra plants were thinned out along with gap filling at 16 DAS. In experiment irrigation water was applying through different PE levels *viz.*, 0.55, 0.70, 0.85 and 1.0.

Five plants were randomly selected from each net plot, tagged permanently and used for measurement of plant height at 6 DAS and at harvest. The five plants randomly selected and tagged permanently in each net plot for plant height measurement were used to record the number of branches per plant (primary and secondary) at harvest and there average was worked out. Five plants were randomly selected from sample row in each plot and carefully uprooted for estimation of dry matter accumulation at 60, 100 DAS and at harvest. The sample plants were dried at sun for ten days and then in an oven at 70°C for about 72 hour till constant weight. After complete drying, plant samples were weighed by an electronic balance and recorded.

Oil content was estimated by soxhlet extraction apparatus. The percentage oil was calculated by using following formula:

$$\text{Oil content (\%)} = \frac{W_2 - W_1}{W_0} \times 100$$

Where

W_1 = Weight of empty extraction flask (g)

W_2 = Weight of extraction flask containing oil (g)

W_0 = Weight of seed taken (g)

The crude protein content in seed was calculated by multiplying nitrogen content (%) in seed with a factor of 6.25 (A.O.A.C., 1990) [1].

Results and Discussion

Growth attributes

Results (Table 1) revealed that plant height of fennel was influenced significantly by levels of irrigation and cultivars. Crop irrigated at 1.0 PE level if irrigation remained at par with 0.85 PE and gave maximum plant height (76.41 cm and 147.22 cm) at 60 DAS and harvest, respectively. It was significantly higher over irrigation levels of 0.55 PE and 0.70 PE. The plant height is a principal factor for growth and development of the crop. Enhancing the plant height due to 0.85 and 1.0 PE irrigation levels through drip might be due to proper management of soil moisture at field capacity. Thus plants absorb proper water and nutrient from soil and increased cell elongation. The lowest plant height at 0.55 and 0.70 PE irrigation levels due to deficient soil moisture near root zone resulting in decline leaf water content as well as cell turgor. Most equal result of enhancing growth attributes with increased irrigation levels at different IW/CPE ratio reported by Bhunia *et al.* (2006) [3] in fennel crop and Mehta *et al.* (2010) [13] in fenugreek. Among cultivars highest plant height (76.06 cm and 140.76 cm) was recorded by RF–205 as compared to RF-101, RF-125 and RF-143 at 60 DAS and harvest, respectively. Inherent characteristic of particular variety plays a vital role on growth and development of crop which might be responsible for plant growth in terms of plant height. These findings are in close agreement with those of Malik *et al.,* (2009) [10], Singh *et al.,* (2009) [19], Sengupta *et al.*, (2014) [17] and Tamboli *et al.*, (2020) [21].

Number of primary branches/plant and number of primary branches/plant were influenced significantly due to different levels of irrigation and cultivars (Table 2). Irrigation at 1.0 PE produced maximum number of primary branches/plant (6.53) and number of secondary branches/plant (8.42) as compared to 0.55 PE, 0.70, but it was at par with 0.85 PE level of irrigation. It might due to proper availability of soil moisture in root zone area and continue increased soil moisture in root area resulting in higher number of branches. According to previous studies Jat *at el.* (2015) [7] reported that significantly higher number of branches per plant was recorded with drip irrigation at 100% of CPE under paired row planting. Maximum number of primary branches/plant (6.03) and secondary branches/plant (8.04) produced by RF-205 as compared to RF – 101 and RF – 143, but it was at par with RF -125. Lal *et al.,* (2019) [9] were evaluated the fennel varieties and reported that maximum number of primary branches/plant, number of secondary branches/plant, recorded in variety GF-12 followed by AF-1. Similar results were observed by Malik *et al.,* (2009) [10], Singh *et al.,* (2009) [19], Sengupta *et al.,* (2014) [17] and Tamboli *et al.,* (2020) [21].

Results revealed that dry matter accumulation of fennel significantly influenced by levels of irrigation and cultivars at all growth stages (Table 2). Crop was irrigated at 1.0 PE recorded significantly higher dry matter accumulation (13.55, 30.01 and 51.99 g/plant, respectively) at 60 DAS, 100 DAS and harvest over 0.55 PE and 0.70 PE but statistically at par with 0.85 PE level of irrigation. The plant expresses good vegetative growth which is well reflected by enhancing in plant height and branches. The optimum soil moisture

condition in the rhizoso here was resulting increased of dry weight accumulation in plants. The moisture stress in root zone resulting reduce cell elongation and photosynthesis leaf area, which lead to decrease in crop growth, and continue increase respiration rate and reduce photosynthesis rate, which ultimate decrease dry matter accumulation. Similar result recorded by Mehta *at el.* (2010) [13] in fenugreek, Godara *et al.* (2013) [6] and Meena *et al.* (2016) [12] in fennel. Cultivar RF-205 (13.03, 28.78 and 48.19 g/plant) recorded significantly higher dry matter accumulation over RF-101, RF-125 and RF-143 at 60 DAS, 100 DAS and harvest, respectively. The plant variety RF-205 expresses good vegetative growth which is well reflected by enhancing in plant height and branches, resulting increased dry matter accumulation.

Quality parameters

Oil content in seed of fennel was significantly affected due to irrigation levels and cultivars (Table 2). Crop irrigated at 1.0 PE recorded highest oil content in seeds (1.67 per cent) as compared to 0.55 PE and 0.70 PE, but statistically at par with 0.85 PE level of irrigation. This finding is reported by Patel *at el.* (2000) [16] and Meena *et al.* (2017) [11] in fennel crop. Cultivar RF-125 recorded significantly higher oil content (1.81 per cent) as compared to RF - 101, RF – 143 and RF – 205 to the tune of 1.37, 1.50 and 1.56 per cent oil in seed, respectively. Protein content in seed was significantly affected due to irrigation levels (Table 2). Crop irrigated at 1.0 PE recorded highest protein content in seed (9.25 per cent) as compared to 0.55 PE and 0.70 PE, but statistically at par with 0.85 PE level of irrigation. Higher nitrogen in seed directly responsible for increased protein in seed because of nitrogen is primary component of amino acid and many amino acid formation of protein. Bhunia *et al.* (2005) [2] in fennel also observed similar results. Cultivars remained non-significant in oil content and maximum oil content was recorded in cultivar RF-101.

Table 1: Effect of irrigation levels on plant height, number of primary and secondary branches of fennel cultivars

Treatments	Plant height (cm)		Number of branches/plant	
	At 60 DAS	At harvest	Primary	Secondary
Irrigation levels				
0.55 PE	59.81	111.10	4.45	6.23
0.70 PE	69.37	132.23	5.16	7.21
0.85 PE	74.94	143.63	6.37	8.28
1.00 PE	76.41	147.22	6.53	8.42
S.Em.±	1.77	3.75	0.21	0.22
CD at 5%	6.13	12.99	0.73	0.76
Cultivars				
RF -101	67.55	129.30	5.45	7.34
RF -125	69.01	133.04	5.82	7.67
RF -143	67.90	131.07	5.21	7.09
RF -205	76.06	140.76	6.03	8.04
S.Em.±	1.79	2.85	0.18	0.21
CD at 5%	5.22	8.32	0.52	0.62

Table 2: Effect of irrigation levels on dry matter accumulation and quality parameters of fennel

Treatments	Dry matter accumulation (g/plant)			Protein content in seed (%)	Oil content in seed (%)
	At 60 DAS	At 100 DAS	At harvest		
Irrigation levels					
0.55 PE	9.85	21.49	33.46	8.31	1.39
0.70 PE	11.35	25.11	42.19	8.69	1.55
0.85 PE	12.88	28.68	49.56	9.02	1.63
1.00 PE	13.55	30.01	51.99	9.25	1.67
S.Em.±	0.37	0.76	1.58	0.18	0.04
CD at 5%	1.27	2.62	5.45	0.62	0.14
Cultivars					
RF -101	11.44	25.40	43.34	9.04	1.37
RF -125	12.27	26.68	45.03	8.63	1.81
RF -143	10.89	24.43	40.65	8.88	1.50
RF -205	13.03	28.78	48.19	8.73	1.56
S.Em.±	0.42	0.94	1.63	0.17	0.05
CD at 5%	1.21	2.74	4.75	NS	0.16

Conclusion

On the basis of experiment, it may be concluded that the irrigation levels 0.84 PE significantly enhanced the growth and quality over 0.55 and 0.70 PE levels but remained at par with 1.0 PE irrigation level. Cultivar RF -205 showed highest growth and quality parameters followed by RF-125, RF-101 and RF-143 cultivars of fennel.

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